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New Space and Agile Innovation: Understanding Transition to Open Innovation by Examining Innovation Networks and Moments

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Abstract

This paper is building a detailed understanding of the organisational structures and practices in SMEs' knowledge absorption from a network of innovation partners. In particular, it explores the relationship between the openness of innovation process through innovation networks and the development of organisational structures within firms, as well as its linkage to a regional sectoral environment. It proposes a new conceptual tool of "innovation moments", to synthesise the key theoretical premises of knowledge management, organisational learning and absorptive capacity literatures. In order to study this vital nexus of phenomena, we propose to deploy a novel mixed methods approach of combining quantitative ego-centric Social Network Analysis (Ego-SNA) and qualitative derived narratives of product development experiences via a sensitising concept, to study the emergence and development of the New Space Sector in Scotland. The findings show that the type of the SME – "traditional" versus New Space and upstream versus downstream – is clearly related to the structure of the firms' ego-centric innovation networks and their position in the composite whole network. Furthermore, by using qualitative case study data we show that the firms' typology is also closely related to internal organisational features, in particular flattening hierarchical structures and the formalisation and standardisation within NPD processes. This paper argues that the interlinking of these two elements is poised to describe a cultural shift in the approach to innovation networking and new product development (NPD) process management, understanding of which is a critical element of examining Open Innovation in SMEs.

Keywords: New Space; Open Innovation; Innovation Systems; Innovation Moments; Innovation Networks; New Product Development; Absorptive Capacity

1. Introduction

The Space Sector is currently undergoing a major industry transition from Space 2.0 to Space 3.0, i.e. into “New Space” [1]. Overall, this is billed as a transitioning away from states and multinational corporations driven markets towards more democratised and de-centralised economic activity based on academic research and small-to-medium-size enterprises (SME) [1–3]. The efficiencies and added value enabling such a shift is built upon significant changes of, on one hand, decrease in cost of developing space technology, and on the other hand, increase in openness and accessibility of space data. Specifically, these changes are enabled by cheaper core technologies (electronics, additive manufacturing / 3D printing), increasing quantity of, and access to, open source data (from public programmes, such as ESA/EU’s Copernicus) and new system/operation solutions (e.g. cloud-based platforms for operation and data management, standard components and “flat pack” hardware) [1,2].

These recent developments enabled new entrants to emerge from traditionally peripheral geographies and though as before the markets are built around three main areas of applications: Earth Observation (EO), (satellite) navigation and telecommunications/broadcasting [4], the New Space players demonstrate a significant amount of growth and have led to the increase in economic and political value and importance of the Space Sector. In this respect, Scotland in the UK is a particularly good example, having formed a very significant subset of the UK’s (New) Space Sector [5] and contending to be second to Silicon Valley in the USA [6]. With three clusters of activity in Glasgow (hardware), Dundee (communication and electronics) and Edinburgh (data analytics), it contains a spread of SMEs over the entire value chain. Furthermore, there is an ambition for the UK to take 10% of the global space industry by 2030 and Scotland to again take 10% of that [7], i.e. 1% of global total.

Despite these significant changes and the economic and political interest these development have generated, their features and implications are poorly understood, as previously outlined by Vidmar [2,8]. There is particularly the need to understand the “organisational structuring and interactions with external partners in the innovation process, and specifically analyse its (inter)dependence on external knowledge acquisition” and “the emergence, development and the current structure of [innovation] links and networks” [2]. These issues are critical to address, both to understand the current trends in the Space Industry, and in particular the implications arising for policy and on-the-ground operations, as well as the wider transformation of previously closed high-tech innovation systems in the transition towards Open Innovation [9–12] as found in a specified locale. Hence, this paper is outlining an in-depth study of the geographically-bound sectoral system of innovation, that of the (New) Space Industry in Scotland, which is now transitioning from an emergent locale to a world-leading powerhouse [6,13–15].

Our work is based on a two-fold inquiry into the innovation networks and the structure of SME’s new product development (NPD) processes [16–18] to show 1) the link between Open Innovation dynamics across intra-organisational connections [16,19,20] and 2) the micro-level SMEs’ organizational behaviour in the absorption of external knowledge, something often referred to as “absorptive capacity” [21–23]. In particular, we are interested in (how) has the structure of innovation networks changed in the transition to more Open Innovation as adopted by the New Space SMEs? And (how) has this transition affected the structure of NPD processes, which are at the core of knowledge absorption into an SME? Furthermore, how can the link between the two levels be best conceptualised?

To answer these questions, we propose a new conceptual tool based on the notion of “innovation moment” [24,25] to describe the connection between the various literatures and studies across these two different levels. In particular, as this study aims to understand the structure of innovation networks [26] and NPD management [27] strategies across different firms, we also focus on examining their propagation within geographical and sectoral configuration. To achieve this, we define a critical innovation systems framing and develop a new a mixed-method research design.

In the following section, we begin by reviewing the two bodies of literature underpinning this research, namely the Open Innovation and Structural Absorptive Capacity takes on knowledge flows. In particular, we expose the need for understanding the mechanics of links between meso-level innovation networks and micro-level SMEs’ NPD processes. In the subsequent methodological sections, we outline how such research can be conducted within a geographically-bound sectoral system of innovation (GSSI), while explaining the deployed methodology, a mixed methods approach combining quantitative ego-centric social network analysis (SNA) and qualitative “innovation moments” study. Finally, we report the results of empirical work within the selected case study, the Scottish Space Sector, and present an analysis of the key correlation between specific features of processual absorptive capacity, the “openness of innovation” and the shape, size and positioning of SMEs’ within innovation networks. We touch on key conclusions, limitations and avenues for further work at the end.

2. Open Innovation and Structural Absorptive Capacity

2.1. Open Innovation in SMEs and Innovation Networks

Small-to-Medium-size Enterprises (SMEs) are facing a very challenging environment in the fast-paced knowledge economy. In particular, increasing knowledge complexity and its wide(er) distribution makes it far more difficult for an SME to innovate by themselves. SMEs address the challenges of the shortage of time, resources and expertise by finding new ways to connect to other (external) actors in order to (out- or in-) source knowledge and generate value out of it. Hence, there is a growing need to create new frameworks and systems to “connect these seemingly disparate activities together” [28] and to make it easier for SME to link-up to other sources of knowledge and expertise. The knowledge flows which are crossing the firm’s boundaries are associated with “open innovation”, a paradigm shift explaining the supra-organisational nature of innovation in some of the most fast-growing economic sectors in the late 20th and early 21st century [9,28–30]. To summarise this, a company that generates all of its innovation internally is considered as adopting a “closed” innovation model, where control over NPD processes and full internal commercialisation of IP is deemed crucial. In contrast, the “open” innovation model is centred on a dynamic interaction crossing the firm boundaries, with some ideas/knowledge being sourced into the NPD process from outside the company, as well as some internal ideas being licensed out from company’s NPD process to others for commercialisation [30].

The mechanisms of open innovation in SMEs are charted by Lee et al. [16] and involve potential insourcing of knowledge and resources (investment), outsourcing of intellectual property (IP), and establishing new business models or entering new markets. Hence, these kinds of interactions with external partners are crucial for understanding the NPD process in SMEs. However, the open innovation dynamic in SMEs is not fully understood, nor is there much analysis as to how the macro systemic level and the micro (open) innovation level are interconnected. In particular, as most processes of open innovation are based on interaction with external partners - and especially knowledge dissipation is done through communication and sharing between individuals and

organisations [31,32] -, a key part of any innovation process is its interconnectedness with “other” actors, processes and systems [20] through (meso-level) “innovation networks”.

Furthermore, several studies have shown that firms’ innovation networks can be related to their performance [33–36], even though further qualitative examination of how and what knowledge is the subject of intra-organisational ties has been called for [20,33]. Specifically, firms in central positions and with internal capabilities are proposed to be benefiting most from an open innovation mode of NPD development [33], regardless of whether they are located in closely-knit “small world” networks or bigger structures [35]. Hence, we hypothesise that the firm’s innovation network structure is related to its degree of openness of innovation process and significant differences should be found when comparing firms adopting the Open Innovation model with respect to those who not. The understanding of these differences can also expose the importance of various (types of) partners in this transition.

The ability to link these meso-level structures with SMEs’ internal capabilities to make use of the networked interaction within NPD is specifically related to the concept of “absorptive capacity”, i.e. the ability to “recognize the value of new information, assimilate it, and apply it to commercial ends” [37].

2.2. Structural Absorptive Capacity and Organisational Learning

Absorptive capacity has been identified by past studies as the crucial approach in conceptualising the understanding of cross-organisational knowledge flows [38,39]. However, Marabelli and Newell [40] found that most organisation studies on absorptive capacity focused on prior knowledge already owned by a firm, and assumed that new knowledge can be easily shared and used, based on the “epistemology of possession” [41]. While this approach is valid, it does not allow for direct observation of the complex processes through which absorptive capacity is mobilised by a firm. In particular, having prior knowledge and open communication channels, even when acknowledging the iterative nature of what happens through these channels, does not fully explain how knowledge is “absorbed” into an organisation and is then used in innovation processes. Instead, the full understanding of how absorptive capacity comes into being has to entail what occurs in practice as firms translate knowledge “into the scene” [42].

Hence, we propose to adopt a processual view of absorptive capacity [22,39,43], which leads us to a focus on practices to recognise, assimilate, transform and exploit external knowledge [21,40]. Processes of organisational learning, as both the embodiment and precursors to establishing the absorptive capacity, are of particular interest [21,44–46]. Noting that both intra-organisational learning through innovation networks, as well as knowledge management within these connections, are dependent on organisational practices and routines [47], leads us to framing absorptive capacity as a structural feature of organisational behaviour. In specific terms, the study of organisational learning and absorptive capacity has been recognised to work best when focusing on new product development (NPD) processes [21]. We specifically propose that understanding the formalisation and standardisation of NPD processes within firms, as well as their management, are a precursor to understanding the structural absorptive capacity. Furthermore, based on past research identifying that organisational learning occurs along geographically and cognitively proximate domains [48,49], we hope to provide specific evidence for such trajectories which can serve as future heuristic devices.

However, these processes are difficult to document directly, as they are relatively abstract in nature. Hence, a more direct epistemological approach is to focus on the new product development processes as the manifestation of organizational practices and behaviors within a real-project

context. Consequently, in order to study the changing structure of absorptive capacity, we derived it into a new conceptual framing for studying the structure of NPD – i.e. the “innovation moments” presented in the next section.

2.3. “Innovation Moment” as a Conceptual Tool to Understand NPD Process’ Structure

Traditionally, the processes of innovation were framed in either linear or cyclical fashion, though neither framing alone was accepted as a sufficiently full account [50]. Instead of such simplistic models, descriptive empirical research has identified that “fuzzy/messy” and complex dynamical processes govern NPD processes in SMEs [51]. Consequently, we are adopting a phased/modular approach, with overlapping stages/work processes, which combines schematic clarity with capturing (some of) the fuzziness/messiness. Hence, there is a need to build a representation of the routines and processes of structural absorptive capacity, which can bridge the different understandings of innovation processes on meso-/systemic and micro-/NPD level of organisational behaviour. This will assist us in understating the (changing) structure of NPD processes undergoing a transition towards Open Innovation.

The proposed unit of analysis in a studied SME is an “innovation project”, i.e. a development of a (single) product, following the CEN/TS standard for innovation management [52]. This analytical approach is based on a distinction between “specific innovation projects” and “general innovation management”, similarly to the Oslo Manual [53], separating “object” and “subject” approaches. The object approach is based on a single business innovation project, e.g. the development of a new product, and the subject approach, which looks at a firm in its entirety. As such, an “innovation project” can be considered a key unit of analysis of innovation in SMEs, which can help us analyse the organisational behaviour by which processes of innovation are managed in a firm, i.e. NPD’s structural set-up, management interventions, etc. Even though there is an assumption that the overall structure of such a project can be synthesised in a generalist way, our research is open-ended and will establish such structure on a “project-by-project” and “firm-by-firm” basis.

Specifically, we propose to deploy the concept of “innovation moments”, which was defined previously by Edwards and others [24,25] as a way to analytically explore procedural phases of NPD, or technical (R&D) or commercial (BD) challenges for the progression of an R&D project. This advanced conceptualisation of an “innovation moment” was derived from a combination of insights from innovation process [54], organisational learning [46] and absorptive capacity [22]. For instance, bridging the gap between the systemic understanding of knowledge flow and its specific local manifestation, we focused on the Sun and Andersons’ [21] proposed combining of lead organisational learning theories with the absorptive capacity framework. Specifically, Sun and Anderson align the processes of intuiting, interpreting, integrating and institutionalising knowledge from Crossan et al.’s [46] theory of organisational learning with Zahra and George’s [22] framing of the processual view of absorptive capacity through acquisition, assimilation, transformation, and exploitation of knowledge. Based on these insights, we developed elements making-up our conceptualisation of the “innovation moment”, by interpreting these four concept in the context of leading NPD stages.

In particular, though precise wording and models vary, most NPD analysis breaks down into several stages or phases, often referred back to the influential models such as the Stage-Gate [55] and Booz, Allen and Hamilton [56]. For instance, the later model lists seven stages: new product strategy, idea generation, screening, business analysis, development, testing and commercialization [57,58]. The first few phases, excluding business analysis but including development and testing, are also referred

to as the “fuzzy front end” of the NPD process [59], whereby the more “creative” and “knowledge intensive” part of the process takes place. Examining this structural view of NPD in more detail, we note that the fuzzy-front-end phases correspond well with the structural absorptive capacity framework. In particular, as seen in Table 1, these are quite complementary and led to the derivation of our own formulation of the innovation moment’ definitions as a four elements structure containing problem/idea definition and analysis, expertise gathering, forming solutions and integration.

| NPD Process Model Phases [57] | Fuzzy Front End of Innovation [59] | Absorptive Capacity / Organisational Learning Framework [21] | Proposed innovation moment elements’ definitions |
|---|--|--|--|
| “New Product Strategy: Links the NPD process to company objectives and provides focus for idea/concept generation and guidelines for establishing screening criteria.” | Opportunity Identification Opportunity Analysis | Acquisition / Intuiting | defining the problem/challenge, |
| “Idea generation: Searches for product ideas that meet company objectives.” | Idea Genesis | Assimilation / Interpreting | gathering the required expertise and knowledge |
| “Screening: Comprises of an initial analysis to determine which ideas are pertinent and merit more detailed study.” | Idea Selection | Transformation / Integrating | forming solutions through knowledge reduction |
| “Development: Turns an idea on paper into a product that is demonstrable and producible.” | Concept and Technology Development | Integration / Institutionalising | integrating the acquired information into the product |

Table 1 - Innovation moments elements' derivation combining NPD process and absorptive capacity / organisational learning insights.

Figure 1 shows that in addition to the conceptual framing outlined above, the derived “innovation moment” structure also contains an implied cycle of product development activity integrating the “problem-solving” aims of NPD [60]. In particular, our conceptualisation aligns with the four-stage NPD experimentation cycle proposed by Thomke comprising of designing the experiment, building its apparatus, running the experiment and analysing its results for use [61]. The “innovation moment” structure also incorporates the cyclic nature of the processes of knowledge management, in particular by focusing on localising, obtaining, evaluating and utilising knowledge [62].

In addition, most analysis point out that the innovation process phases more broadly are not a linear sequence either, but occur simultaneously, with different aspects brought into the focus of the process at different, of then multiple, times [50]. Similar stages and cycles of knowledge management within innovation/NPD process were previously also identified empirically in a variety

of literature, in particular Open-Innovation-driven Living Labs [63], however, without formalising a conceptual tool such as “innovation moments”, or contextualising it within a knowledge management, organisational learning or absorptive capacity frameworks. Hence, in order to explore the proposed conceptualisation empirically, both on firm-by-firm as well as on more systemic levels, a vital novel methodology needed to be developed, as is outlined in the next section.

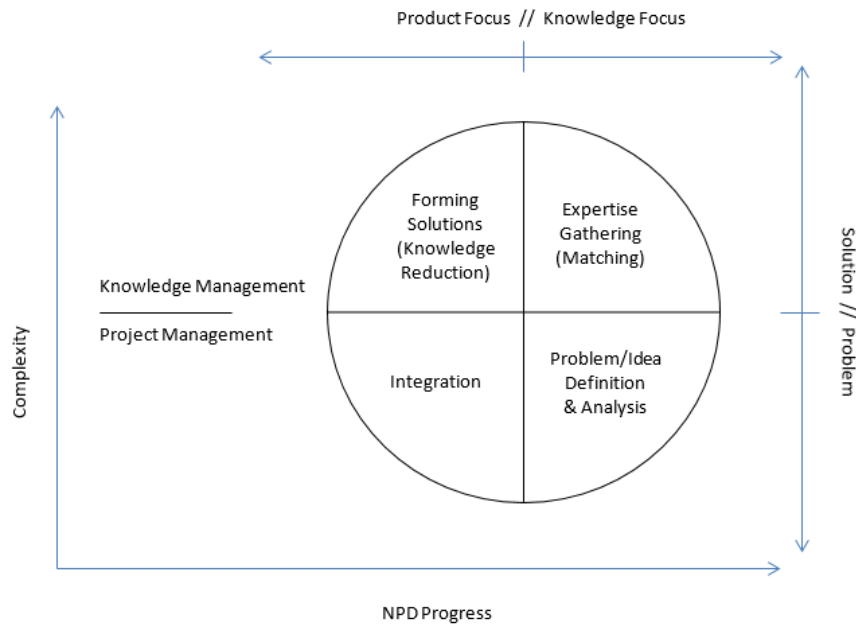


Figure 1 - A schematic diagram of an “innovation moment” – a new analytical tool for NPD process research.

3. A Multimethod Study of Innovation

Although we already argued that link(s) between the innovation networks and the localized innovation processes in NPD are key, very few studies merge research of networks with the details of the interaction. In particular, more work is needed to understand the nature and propagation of knowledge, the activities related to the integration of network sources knowledge in developed products and the mutual co-shaping of product development/innovation processes and the innovation networks [45].

The key principle of our analysis is that innovation is a process centred around people in organisations, their behaviour and decisions [54]. Thus, the key processual stages and development challenges at which the contested reality comes into foreground are the decision points at which the innovators have to decide the future of a project in face of a challenge to bring it to the market, i.e. what Swann calls development work [51]. The identification of these key points within NPD and the way in which the environment – in particular interactions with external and internal sources of knowledge, technology and skills - is affecting those decisions, is vital for the understanding of the overall process, and this is the chief purpose of this empirical analysis.

Methodologies for dealing with the study of the contextual environment of innovation process, embedded in systemic elements, i.e. macro-level landscape, are well developed (and contested) within the innovation literature [17]. However, linking those top-level approaches to specific instances of innovation in actual product development is methodologically underdeveloped. In particular, studying innovation in SMEs is challenging due to several factors, such as short timeframe, unclear boundaries, the informality of operations and access difficulties. Consequently, a

suitable geographical-sectoral innovation system framing is required, as presented in the next section. In addition, we developed a mixed-methods framework, inspired by the “strategic ethnography” principles within biographical approach to innovation studies [64], with a core two-fold inquiry. The evolving innovation network and its interconnectedness to specific NPD processes can be examined best through a mix of quantitative Ego-SNA techniques, while firms’ practices are best studied qualitatively using a “sensitising concept”.

3.1. Defining Geographically Bound Sectoral Systems of Innovation

Overall, the empirical insights from a mixed ego-SNA and qualitative semi-structured interviews will be used to advance theorising on the nexus between systemic innovation networks and firm-level NPD practices, following the case study-based theory building approach [65]. In comparison to most other proposals [66], our methodology defines a much broader framework of inquiry of how innovation network(s) operate and what effects they have on specific innovation processes. However, in order to analyse this nexus in sufficient detail, it is important to pick an appropriate case study [67]. In particular, we chose the Scottish Space Sector for our subject of study, as it is important for it to be of a size allowing for in-depth study, whilst also being comprehensive and complete, i.e. actors along the whole value chain and at all stages of development. Furthermore, in order to satisfy our theoretical interests, the studied case should be a clearly defined sector, and specifically for this research, being high-tech, fast growing and transitioning from closed innovation models and high-level corporate stakeholders to a dynamic open innovation arena and a consumer-driven market.

In order to conceptualise such a setting, geographically-bound sectoral system of innovation (GSSI) framing was developed. In order to homogenise the knowledge and technologies (sector) and institutional (geography) framing – as well as expose “actors and networks” as one the critical subject of research [68]. Such an approach is also in direct alignment to the analysis of the need within Open Innovation paradigm to jointly study NPD-network innovation dynamics across the SMEs boundaries, as outlined earlier.

GSSI has been fundamentally based on a very successful framework for the study of intra-organisational phenomena of innovation, namely the Innovation Systems (IS) [69]. It has been shown that the innovation systems model can be framed using geographical boundaries such as national [26,70–72] or regional [73–75] units, or by separation of economic activities to (different) technological [66,76] or sectoral [77–79] platforms. These different levels of inquiry however by and large share the same common framework of the Innovation Systems tailored for scope and aims of different researchers’ interest [80]. For instance, as noted by Edquist, system boundaries can be drawn in three different ways: geographically; sectorally; and in terms of system activities or functions [75,81].

Hence, in our defining of boundaries of the studied system we rely on the proposition that any entity deemed to be part of such a system has to be within the geographical boundaries of the studied locale (region) as well as part of a value chain of a specific innovative endeavour [82,83], which is recognised as a constituent of the studied sector. Similar to Malerba’s definition of a “sector [being] a set of activities which are unified by some related product groups for a given or emerging demand and which share some basic knowledge” [68]. So far, the research in Sectoral Systems of Innovation (SSI) has mainly focused on sectors of industrial production, even though the framework has also recently been adopted in studying more knowledge-intensive sectors [84], in particular, biotech [85], pharmaceuticals [86] and IT [87].

3.2. Examining Innovation Networks

We propose to use ego-centric Social Network Analysis (ego-SNA) [88] to analyse the innovation networks of (key) studied companies. Our work here follows the approach of Giuliani [89,90], who have been researching knowledge networks and their ability to acquire and deploy knowledge in order to innovate. Though we are more interested in the process of innovation, in particular, the direction of the “knowledge flow” and the level of networks’ integration in the NPD process, the examined qualities are similar [18].

The focus of this part of the inquiry is on mapping the relationships between the studied firms and its partners, in particular partner’s importance for the studied company, which is measured both in subjective terms (ranked on a 1-5 Likert Scale by the interviewee) as well as by collecting information about frequency and depth of the connection (in terms of the number of employees within the studied company who are engaging with said partner). This is then analysed in conjunction with the qualitative data about the firms’ NPD processes.

Furthermore, as the aim of this study is more specifically the qualitative description of the absorptive capacity within the NPD process, special attention is being paid to the knowledge flows and their direction. Data was also collected on the typologies of collaboration with respect to “purpose” (i.e. is it about R&D, business development (BD) or commercial interests); “nature” (i.e. the degree of formality and depth of involvement – for instance transaction vs partnership, type of partners involved); and the “result” (i.e. knowledge flow - IP ownership) of firms’ relationships with external partners. Though some of this data will be discretely plotted in the individual firm’s ego-SNA network map, most of this information will be summarised and contrasted qualitatively. This part of the data collection is based on interviews using a closed questionnaire, with multiple-choice answers, but options for other (more expanded) answers as well. This survey is fully incorporated in the “data matrix” and is filled out with a mix of discrete conceptual (e.g. frequency of contact, types of relationship, etc.) and numerical categories (e.g. Likert scale of importance, number of staff interacting with partner, etc.).

After plotting and examining the innovation network for each of the selected typical cases of the studied companies, the networks from all actors across the sector are to be combined into a composite whole socio-centric innovation network of all Scottish New Space SMEs. This is achieved by cumulatively mapping all the ego-net ties (i.e. connections) on one network map [91] and can then be subjected to a variety of SNA statistical tools to assess individual actors’ network centrality. In particular, undirected eigenvector centrality can be used to sort the actors (network nodes) according to their position within the composite whole network. Such a measure of centrality can be used to demonstrate which actors are integrating the studied (innovation) network and correlated to qualitative data to analyse the reasons for the positions they occupy.

3.3. Mapping Out NPD Processes Through “Innovation Moments”

In order to analyse these network structures with respect to the effect(s) they have on the NPD process, we developed a qualitative section to our study based around identifying and examining the previously outlined “innovation moment”, here used as a “sensitising concept” [92] to standardise the data collection in the presence of a diverse set of ontological phenomena [93]. As described earlier, the proposed “innovation moment” framing is reflecting a wide variety of theoretical conceptualisations as outlined earlier, as well as having a degree of interpretative flexibility (i.e. not applying directly to any single theory) and can be easily explained through specific operational functions (i.e. using common language and specific examples). In particular, it contains embedded structural questions about the operation of the firms NPD processes, which is the objective of the

research into the link between external open innovation networks and internal structural absorptive capacity. A schematic diagram of the “innovation moment” conceptualisation was presented in Figure 1 earlier, including its contextualisation as a problem-solving exercise within the wider analysis of organisational (knowledge) management within SMEs.

The data collection stage here was to ask specific questions relating to the formation of a “problem definition”, following through “expertise gathering” and “solution formation” towards “integration” in the next phase of NPD process, at which point the cycle is repeated. This structure enables maximum attention to be paid to the involvement of external actors within the NPD process, as it respectively examines identification, acquisition, selection and alignment of internal and external resources. We asked each of our interviewees to talk about two R&D projects and to think about five to seven “innovation moments” for each. The informants are then asked to describe these key instances by outlining what a specific “moment” had been about, how the R&D/BD team framed it, how they looked for “solutions”, how they picked the “solution” they considered best under the circumstance, and how that “solution” was integrated in the product/service being developed. A particular focus was on the engagement of external partners and the way in which the NPD process is structured and managed, which were extracted and analysed in a later section.

3.4. Selecting the Case Study

The emerging Space Sector in Scotland is providing an excellent platform for this research. In selecting the case study, we decided to use the geographical framing of Scotland due to the size, comprehensiveness, homogeneity and dynamism considerations, and the sectoral framing of Space Industry. The sector is analytically defined through product groups, which can be either split along different technologies, such as satellites, transmitters, detectors and data management systems or applications, such as earth observation (EO), telecommunications/broadcasting and satellite navigation.

With the help of gatekeepers and by attending over 30 open industry events, we have identified all of the sector’s core SMEs and conducted a detailed mixed-method analysis of their innovation network and NPD process, using the methodology outlined above. Detailed analysis of the companies in the Space Sector in Scotland led to the identification of nine types of SMEs which can be categorised using double-crossed qualifiers as a set of typical cases [94], see Table 2 below, which was based on a previous scoping exercise [95]. The qualifiers applied relate to the level of maturity of the examined firms, which emerges as cross-correlation of size and age of the SME, and its position in the value chain, broadly described as upstream, mid-stream and downstream respectively. The latter qualifiers were derived from the standard-bearing OECD analysis of the Space Economy [96].

| | Software | Sub-systems & B2B Services | Hardware |
|---|--------------------|----------------------------|------------------|
| | <i>Down-stream</i> | <i>Mid-stream</i> | <i>Up-stream</i> |
| “New Space” / Emerging (established since 2012) | ND | NM | NU |
| “Transitional” / Consolidated (established 2002-2012) | CD | CM | CU |
| “Classical” / Established (before 2002) | ED | EM | EU |

Table 2 - A table of nine typical cases for Scottish Space SMEs’ analysis, categorised by value chain position (down-stream, mid-stream and up-stream) and the length of presence in the sector/industry outlook (established, consolidated, emerging).

4. Results: Emerging (New) Space Sector in Scotland

The key empirical findings from the deployed two-fold inquiry are presented in the two sections below. We begin by examining the innovation network aspect, followed by the analysis of the NPD process, before bringing it all together and contextualising the findings within the examined literature in the discussion section. We focus in particular to the nine selected typical cases.

4.1. Emerging Innovation Networks

The dynamics of the nine ego-centric innovation networks show clear indications of significant structural changes in the size and characteristics of the innovation networks, as one compares the “classical” versus New Space aligned companies, as well as defining differences between upstream (hardware) and downstream (software) segments of the value chain, as seen in Figure 2¹. The ego-centric SNA innovation network graphs clearly show differences in size, composition and geographical density of the innovation networks from the “classical” towards the New Space companies, with underlying upstream-downstream background differences notable as well.

¹ Mirroring Table 2, the graphs are organised from the “classical” on the bottom, via the “transitional” in the middle and to the “New Space” on the top and from “upstream” on the right through “midstream” in the middle and “downstream” on the left.

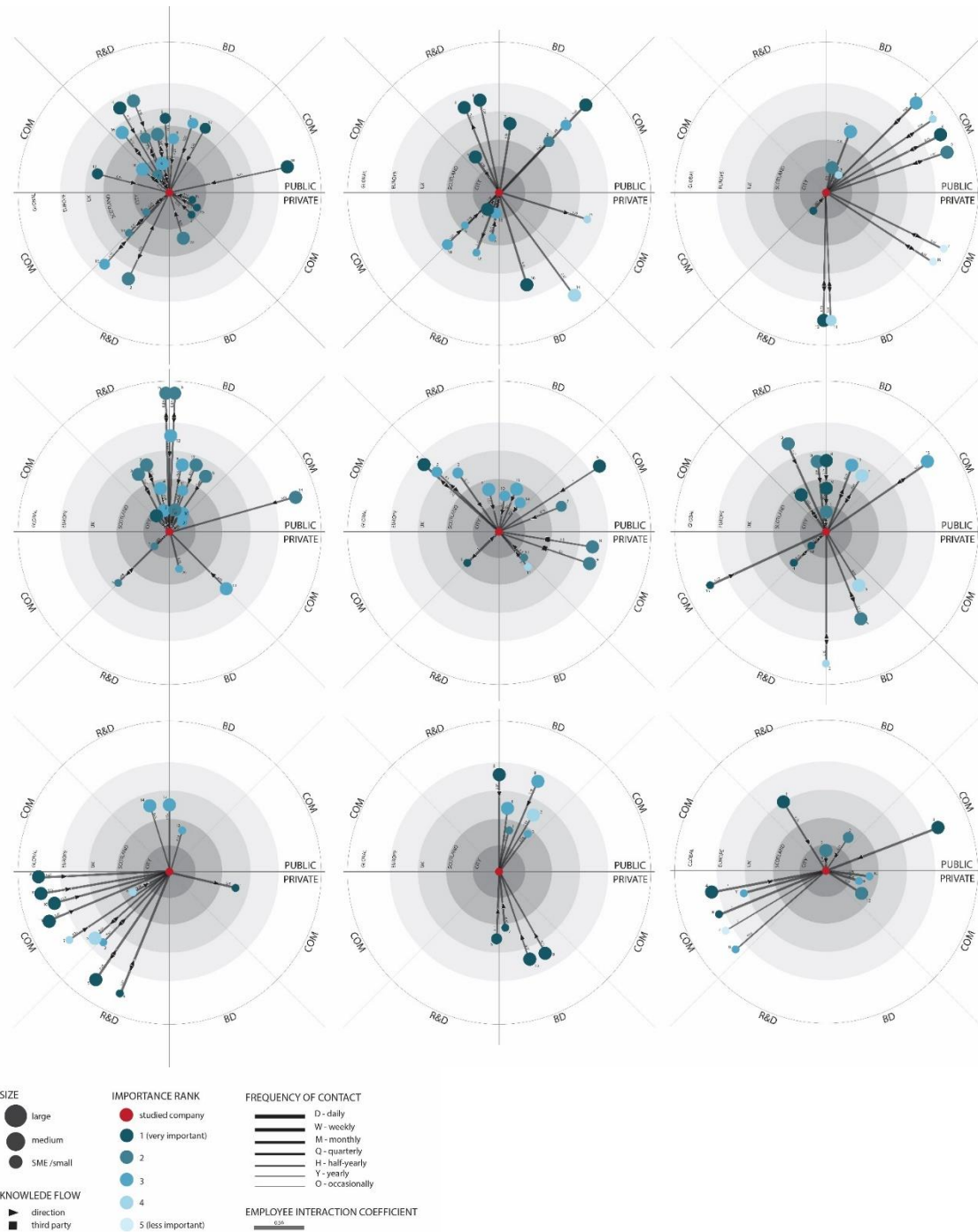


Figure 2 - Ego-centric innovation network maps for nine typical cases of the studied SMEs.

The networks are getting larger in the direction from established “classical” hardware SMEs (EU) towards the emerging New Space companies (ND). Similar trends were discovered in the public- to private- sector partnership ratios, and the levels of commercial activities, R&D and BD (i.e. relationships’ “purpose”). The more New Space a company is, the more it partners with public organisations for R&D, BD and commercial transactions, and the more such partners it has. In contrast, more “classical” Space companies have more private sector partners, mainly engaged in purely commercial activities, such as distributors and suppliers. This trajectory is graded with the “transitional” companies (CM-type) in a clearly intermediate position, with a moderate degree of openness of innovation, network size and structure, and matching NPD characteristics.

Geographical proximity is often considered as an additional measure of strength [49,97,98] and we observed that the “classical” Space companies have a much more global network in comparison to the New Space ones, for which the network density is much higher in the city of origin. Scottish cities, due to their highly educated workforce and good provision of facilities and services, are commonly seen as an asset for developing and growing high-tech clusters, for example, biotech [99]. Specifically, during the qualitative interviewing, one of the interviewed CTOs (from the ND firm) noted:

“When I go to Harwell [the definitive UK Space cluster] there is a lot of Space companies clustered together, but it is just Space [...]. I think what Scotland needs to champion is the idea that our Space Industry is embedded in larger entities – which is the cities. [...] I think what Space needs to do is to move out of the Space Industry and into these other sectors and I don’t think that is something you can do in a campus environment like at Harwell, it needs to be in a city environment where they are surrounded by other non-related sectors.”

All studied firms had an even mixture of strong and weak ties (both by qualitative assessment on Likert scale as by quantitative measures of frequency and depth of interaction). The ties typology (“nature”) has also changed, but insignificantly with a clear dominance of formal/contractual relationships, though New Space firms mentioned having informal relationships in addition to formal ones. However, weak yet significant differences are noted in formal “knowledge flow” measured by sharing of IP, though very much depending on value chain position. In the downstream segment, there is no detectable change between SMEs’ generations (ED, CD, ND), whereas in the upstream part (EU, CU, NU), there are significantly more joined or third party IP ownership arrangements amongst the younger, New Space firms.

Finally, when examining the whole network (see Figure 3 and background data in Appendix 2: Core Innovation Network Data Table) we note that the central role in this regional sectoral network is occupied by a series of public stakeholders, agencies and institutions (European Space Agency, UK Space Agency, Scottish Centre of Excellence in Satellite Applications, Scottish Space Network, Innovate UK, Scottish Enterprise, etc.) who intermediate in the innovation process, pointing to an increasing importance of public R&D and BD support for New Space SMEs. This is also apparent from the firm-level network expansion into the public sphere, as noted in the firm-level ego-SNA analysis.

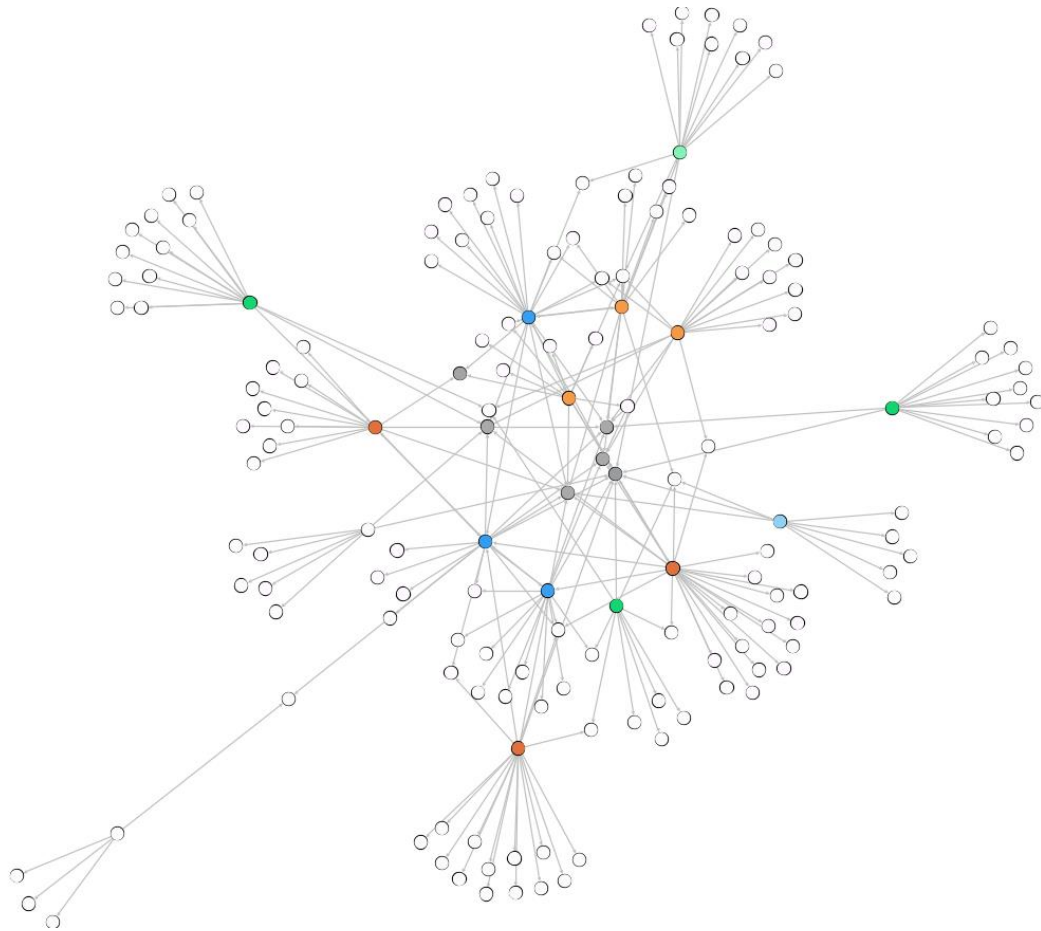


Figure 3 – The composite whole Scottish Space Sector innovation network.

In addition, some notable consolidated companies (CU and CD -type in particular) were also found to be very centrally positioned in the composite innovation network, being most dominant in the process of developing the current vision for Scotland's Space Industry integration around a joint loose value chain, also referred to as "Agile Space" [2,8]. Furthermore, the expansion of the sector is seemingly driven by external forces, as it does not couple very closely with the initial sectoral core (EU, EM and ED type firms).

This indicates the importance of the transition to New Space's open innovation model for the network structure, since it is adopted by the centrally positioned emerging and consolidated firms. On top of that, there is also significant role of interventions by innovation intermediaries in the network structure, as noted by their central bridging position.

4.2. The Changing NPD Processes

When moving to qualitative data, analysed through the framework of Open Innovation [100], we again find a very clear divide between upstream and downstream; and "classical" and New Space, as EU-type companies tend to exhibit more "closed" innovation models than ND-type ones. Analysis of all of the firms' NPD processes suggests that the more the innovation process is "open" the less hierarchical it is, but also the more structured/standardised and formalised in well-defined "phases", such as defining requirements, exploring technological limitations, prototyping, engaging with clients, etc., as seen in Table 3. This is in line with anecdotal experience from most successful high-tech areas, where more formalised, yet less restrictive NPD protocols are being established in order to capitalise on as much innovation as possible [101].

Such organisational changes were identified by two interrelated trends, the NPD teams are larger and more diverse and crucially, the firms are breaking down the traditional workplace hierarchies. Instead of the firms' management teams leading the process directly (like in the case of ED, EM and EU), the youngest, New Space companies (ND, NM and NU) only coordinate the development of NPD structures from the top - i.e. road-mapping, development of work allocation and procedures - whilst day-to-day innovation work is handled by a dedicated new role of "project manager" or "developer". This enables a greater and more successful integration of interdisciplinary expertise and more diverse engagement of internal and external partners through "relationships management". Smaller firms also highlighted the emerging need for "subcontractors management", recognising similar requirements to manage transactional costs and the challenges of outsourcing any part of NPD.

These organisational management changes are also related to the emerging dominant commercialisation strategies, which are moving away from IP protection regimes and towards first-to-market and product differentiation as unique selling points (USPs). This is likely due to the changing balance from engaging in a "technology push" business model, with dominance of business-to-business customer relationships, towards a more "market-pull" model with a wider array of clients, i.e. selling to the "end user". When examining the products developed within studied firms, the latter model seems to lead to products with a lower level of technological advantage (i.e. "incremental innovation"), but with an increase in knowledge complexity (i.e. additional incorporating product design, behavioural science, marketing, etc.) and yet at the same time also user-friendliness (i.e. ease of use, ease of installation and integration with existing technologies, wide distribution, etc.) – leading to very competitive market position.

| | Software | Sub-systems & B2B Services | Hardware |
|---|---|--|--|
| | <i>Down-stream</i> | <i>Mid-stream</i> | <i>Up-stream</i> |
| "New Space" / Emerging (established since 2012) | Structured NPD process including well-defined stages (user-defined requirements, technical requirements, prototype, beta release, etc.) Specified Project Manager role for coordination and oversight | Structured NPD process with defined phases (defining requirements, identifying potential technological solutions, clarifying client needs, defining the product, development, prototyping, testing, release) The whole company (8 people) involved in coordinating all projects, but with management leadership | Started unstructured, but now a structured NPD process, with well-defined phases and template documentation Self-nominated Project Manager (whoever starts the paperwork) leading the development |
| "Transitional" / Consolidated (established 2002-2012) | Semi-structured NPD process (processes in place, such as regular meetings and briefings, but phases differing from project to project) Management oversight, but led by project developers (engineers) | Semi-structured approach (defined phases, but informal), key stage "productisation" for ease of use and mass production, adopting software NPD process methods Management team has strong oversight | Structured approach for some projects (core business) and unstructured for others (pathfinders) Project development lead for pathfinder projects, but with strong management control |
| "Classical" / Established (before 2002) | Unstructured NPD process (ad hoc project development) Management oversight and control of NPD | Unstructured NPD process (significant difference between projects) Strong management leadership and control | Started very unstructured, now semi-structured NPD process with very loose and informal stages (design, prototyping, testing) Management team in control of NPD |

Table 3 - Structure of NPD processes and their management within the nine case study SMEs

The deliberate decision to develop such business models was fully acknowledged by most of the New Space companies in the sample (ND, NM, NU) and the wider population, with explicit comparisons drawn to competitive markets such as video streaming (i.e. “becoming the Netflix of EO data”) and their sales techniques, for instance creating programme loyalty, defining unique selling points and niche exploitation. Furthermore, the process of delivering products and services to the market, as well as their positioning in those markets, was described in terms of defining user requirements. For instance, working with lead users to test pipelines and package products as platforms, to allow for maximum flexibility and continuous updates and upgrades (as short as 4 months and 6 months product improvement cycles were cited). This approach is being adopted by the consolidated-type firms as well, as the CD’s representative underlined that they are now looking at developing products “not for a client, but for a market”. Transitional CM’s CTO picked up on the same trend, noting that his firms is changing: “instead of fixing requirements, accommodate for the fact that things change”.

Such an “agile” approach to NPD also translates into SMEs’ business model flexibility, as several of the studied SMEs started in education markets, from where the core New Space R&D emerged. However, soon they moved to commercial opportunities within other domains, in particular agri-tech and financial markets, the latter particularly notable in the NU-type companies. Likewise, several downstream firms (CD-like and ED-like) moved from Earth Observation analytics for environmental protection towards agri-tech, too [2]. Interestingly, these trajectories are similar regardless of whether the companies were spin-offs from research or entrepreneurial start-ups. Though some of the smaller firms analysed look for any new opportunity to supplement their portfolio of projects and revenue streams, many of the companies developed their “vision pitch” to position themselves in a well-defined (niche) market. Crucially, most downstream companies, in fact, do not highlight their Space and Satellite credentials, but prefer to highlight competencies in data analytics instead.

In contrast, the upstream firms do emphasise their high-tech Space Industry credentials and appreciate the value of an endorsement from big players in this arena, in particular, the European Space Agency (ESA). Though they often find engaging with ESA challenging - due to the Agency’s complex policy framework(s) as well as significant project management requirements leading to bureaucracy - ESA certification through participation in R&D programmes, subcontracting or the adoption of quality assurance standards is desired by most New Space upstream firms.

5. Discussion: Diffusion of Open Innovation through Embedding Absorptive Capacity into the NPD Processes in the Geographically-Bound Sectoral System of Innovation

From combining SNA and “innovation moments” analysis, it is clear that a significant link exists between the shape and size of an SME’s innovation network, their centrality in the regional sectoral network and the structure of their NPD processes. Specifically, the level of formalisation of the NPD process - with clearly defined roles and procedural steps, complete with detailed paperwork trail and resources management measures - corresponds to SMEs establishing and maintaining a larger innovation network of varied partners. This brings more significant knowledge flows across the organisational boundaries and their more central location within the regional sectoral network.

In line with this papers’ main objective, we hence put forward a perspective of the absorptive capacity as a structural property of the SMEs’ organisational behaviour, contributing to firms ability to connect into (a receptive) external environment. This is the basis for the firms’ absorption of

knowledge in a more “open innovation” fashion, through engaging in knowledge exchange with academic institutions and researchers [102,103], enrolling lead users in development to actively shape products and services [104,105], and participating in a variety of opportunities to explore competing options for market formation and pathways to commercial exploitation of R&D [9,16]. Such wider, system-based innovation/R&D operations are also linked to more intensive support by innovation intermediaries [106,107], also noted for their centrality within the analysis of the Scottish Space Sector’s innovation network outlined earlier. One would be tempted to propose that as a consequence, the structural framing of absorptive capacity is more independent of the traditional measures of geographical and cognitive proximity, as it is deliberately shaped through organisational structures within firm management. Though the availability of external knowledge is an important consideration to shape the environment within which the organisational behaviour is to take place and is crucial in enabling its success, the structural organisation is vital for the SMEs to successfully seek, identify, select and integrate the knowledge needed in their NPD process. This would relate to the critical role of management teams in encouraging absorptive capacity as noted by previous studies [45,108,109].

However, there seems to be an uneven uptake of the open innovation approach within the studied sample, as the upstream firms, even the younger ones, are exhibiting these structural changes less strongly. In fact, the recruitment model of knowledge acquisition [110] is still quite prevalent within most of the upstream firms. This is in part related to the nature of the technological challenges they face, the structure of their markets and competitors, and other cultural differences related to varied “epistemic cultures” [111] between the hardware upstream manufacturing and the software downstream application development. The latter is a particularly interesting observation, since the downstream firms, operating within the broader ICT sphere, tend to exhibit many of the features of the entrepreneurial culture of the ICT sector in the 2000s and 2010s [112–114]. This includes a relaxed workplace environment, flatter management hierarchies and a set of measures to “boost innovativeness and creativity” [115]. This “culture” is becoming pervasive across the New Space segment of the Scottish Space industry, as even one of the NU-like firms’ CEOs interviewed specifically commented on their approach to innovation within the firm as: “follow your nose and get creative!”.

Hence, in terms of developing the absorptive capacity itself, we suggest that organisational learning has in fact occurred along geographically and cognitively proximate domains, similarly to previous findings [48,49]. In our case, this occurred in two phases: firstly, through the downstream New Space companies, as they most closely align with the IT sector from where many of these ideas originate, and from where the NPD process management features described here likely originate. Secondly, these lead firms’ share geographical proximity and sectoral identity with mid-stream and upstream SMEs within the examined GSSI, through which they further diffused their new insights into NPD management and other aspects of the emerging “innovation culture”. In particular, one of the studied “transitional” firm’s (CM) CTO specifically mentioned: “[...] it’s about taking things [NPD management practices] from app developers and applying them to hardware.” It is clear that this is being spread further up the value chain as well, since the NU’s CTO described their NPD process as “applying design thinking to hardware”, specifically taking ideas from Silicon Valley and basing their approach on “empowering people to compete”. An example of this is their change of the NPD process from unstructured and management-led towards more structured and with self-nominated project managers (“whoever starts a document is in charge of it”).

These trends also correspond to the emerging Agile Space conceptualisation of the sector’s value chain integration, which is being proposed by a series of lead players in the middle/consolidated

generation of the Scottish Space actors, in particular firms of the CD and CU type. These are New Space trends adopters, who have already established the critical size and sectoral position to influence other firms. Their efforts are based on their vision to achieve a cross-regional vertical value chain integration as a loose consortium of SME-type firms, making Scotland a one-stop-shop for space assets, yet ensuring greatest possible flexibility, openness of the system (notably in its ties to academia) and resilience in face of competition [2]. Thereby the highly projectised NPD process serves as the enabling organizational principle for inter-firm linkages, supported by an extensive, dense and centrally integrated cross-sectoral network.

6. Conclusions and Further Research

The main aim of this paper was to illuminate the transition towards open Innovation by the changing structure (size and composition) of SMEs' innovation networks and changes to the structure of NPD processes, as points of absorption of knowledge into the firm. This has been examined through the combined ego-SNA mapping of innovation networks and qualitative analysis of NPD processes through the newly developed conceptual tool of "innovation moment", bridging the meso-level networks and micro-level processes and deployed as a "sensitising concept" within a case study of a geographically-bound sectoral system of innovation.

When studying the Scottish Space Sector through the proposed framework of combined NPD-network analysis, we are seeing a very clear graded transition trend between upstream and downstream, and "classical" and New Space firms. Upstream "classical Space" companies tend to exhibit smaller though more global and commercial innovation networks and more hierarchical and erratic NPD process than downstream New Space companies, which have larger yet more local networks with more public organisations as partners. They also have more standardised and formalised NPD, breaking down hierarchical organisational structures, but with clear management strategies. Finally, the whole network analysis shows how central positions are occupied by more New Space companies (with slightly more established firms taking a lead over the new entrants) and a critical network integration role for innovation intermediaries.

On the basis of these empirical findings we examined the role of absorptive capacity [21,22,37] in Open Innovation [16,23,28], and its processual operationalisation through NPD structures, which we found to be transferred from other recently emerging high-tech sectors. We identified an emerging trajectory for such adoption through organisational learning, transferred across geographical and cognitive boundaries, from the cognitively adjacent ICT sector, through downstream Space SMEs, and towards the geographically proximate upstream Space firms. These results demonstrate a significant alignment between expanding innovation networks and increased projectification of NPD processes, leading towards a structural construction of absorptive capacity. In addition, the mapping of the whole innovation network also points towards key roles for innovation intermediaries and consolidated firms in promoting organisational learning and developing these systemic capabilities. For instance, on top of expanding the "open innovation" approaches within the sector, they are also driving the establishment of a collective vision of a loosely co-joined vertical value chain integration, a systemic model through which Space Industry in Scotland is establishing a globally recognisable brand [8].

This was brought about through key players adopting a more "agile" business models, in order to dynamically respond to new customers and markets [2]. Such an approach is made possible through adaptation of the firms' "innovation culture" to be able to quickly address these new opportunities, in ways adopted from most dynamic sectors. Specifically this is done through deploying novel NPD

process management techniques², which are developing absorptive capacity and expanding their innovation networks. Having established and tested our novel conceptual framing of “innovation moments”, we believe it can be used to explore this transition in any geographically-bound sectoral system of innovation domain.

Though this study aimed to be as comprehensive as possible, the relatively small population of Scottish Space SMEs limited the ability to infer results by deploying statistical measures or to propose strong correlations between the examined elements. However, we believe that the identified trends and the advancement of the methodological approach to the study of these phenomena constitute a significant original contribution to the understanding of open innovation in SMEs. It shows absorptive capacity through innovation networks, while it also provides some crucial insights in the development of the Scottish Space Sector.

In terms of possible further research, we propose to examine comparable cases elsewhere. With the goal of developing understanding further, the “innovation moments” conceptualisation combined with the multi-level methodology developed and presented within this paper are suitable to further illuminate the mechanics of building “absorptive capacity” within firms through organisational learning trajectories. To do so, a more detailed theoretical development on the links between “innovation moments” and the absorptive capacity and innovation network frameworks are needed. Furthermore, some of the key transformative network elements and organisational management principles which have been outlined here, require further empirical examination to understand their exact origin, characteristics and effects. As mentioned, this is particularly true for innovation intermediaries, who play a pivotal role in the development of this emerging New Space innovation.

² Additional ethnographic evidence shows an ever broader cultural impact, for instance, most of the New Space firms visited have architectural features and furniture in their offices which are intended for relaxing or play as well as communal meals (for instance billiards or football tables, bar/kitchen, lounge/common room, outdoors areas, etc.). This is in stark contrast to the “classical” Space companies, whose premises do not have these features.

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Appendix 1: Outline of the Empirical Work

The empirical work is based on an in-depth analysis of all Scottish Space Sector core SMEs, in particular their NPD and engagement with other actors in their innovation networks. A list of Scottish Space Sector SMEs was compiled using publicly available data, gatekeepers intelligence and a multi-criterion filter consisting of:

- conforming to SME firm description (fewer than 250 employees, less than £25M turnover and less than £12.5M in gross assets),
- are based in Scotland (according to Companies House data),
- one of core business/product/service groups falls within the Space Economy value chain,
- they are actively developing new products and are near completion on at least one NPD project by end of 2017, and
- they are economically active and have a noticeable presence within the sectoral ecosystem (attending conferences and other events, updated website, filling annual tax returns).

This led to the shortlist of 17 Scottish Space Sector companies, with which in-depth interviews (up to 2h) were carried out with a member with each of these firms' management team (CEO, CTO or Business Development Manager). In line with the research objectives, these were the questions addressed:

- a) How does the company source knowledge/technology/business development skills? What kind of knowledge is transferred (tacit, codified, skills, experience, etc.); How is it transferred (informal contacts, (research) partnership/collaboration, recruitment, IP transactions)?
- b) What/who is the main source of new ideas/technology/business development? Who are the key external contacts (actors)? What kind of role does the company play in the regional/sectoral network and how does that change? (Using ego-SNA)
- c) When and how do these sources feature in company's NPD (R&D and BD inclusive)?
- d) Provide a description of (complete) NPD. Describe stages/processes/structure; who is involved (in which part); what kinds of problems/themes are addressed (and in what sequence)?

Additional (non-structured) input was obtained from a variety of other actors in academic and research environment, from bigger firms, public bodies and development initiatives. We have also attended over 30 industry events across Scotland, UK and globally, collecting information from a variety of stakeholders.

Appendix 2: Core Innovation Network Data Table

Table 4 - Whole Network Data Table (up to all case studies) Table 4 contains colour-coded data on the all central nodes within the composite Scottish (New) Space Sector network (presented at Figure 3), as sorted by eigenvector centrality, up to the cut-off point of encompassing all nine typical cases SMEs. This list clearly both validates our sampling method, as the all the key typologies appear in sequential order, as well as shows the core of the network positionality and influence distribution trend from consolidated downstream to upstream and from "traditional" to "New Space" firms. The slight dominance of the "transitional"/"consolidated" firm class is related to level of maturity (N-type are too young to have central network role) and the relative completion of transitional arrangements into New Space (C-type have led the transformation and now behave as New Space firms).

| Identifier | In-degree | Out-degree | Degree | Authority | PageRank | Undirected Eigenvector Centrality (sorted) |
|-----------------|-----------|------------|--------|-----------|----------|--|
| CU | 5 | 15 | 20 | 0.0345 | 0.0686 | 1.0 |
| ND | 1 | 24 | 25 | 0.0521 | 0.0200 | 0.9300 |
| CD | 2 | 21 | 23 | 0.0427 | 0.0303 | 0.8977 |
| Intermediary 1 | 11 | 0 | 11 | 0.0213 | 0.0727 | 0.7546 |
| Intermediary 2 | 8 | 0 | 8 | 0.0151 | 0.1607 | 0.6661 |
| CM | 2 | 14 | 16 | 0.0305 | 0.0429 | 0.6438 |
| ND-like 1 | 0 | 12 | 12 | 0.0233 | 0.0530 | 0.5825 |
| Intermediary 3 | 8 | 0 | 8 | 0.0152 | 0.125 | 0.5644 |
| ND-like 2 | 1 | 14 | 15 | 0.0275 | 0.0330 | 0.5524 |
| NM | 0 | 19 | 19 | 0.0432 | 0.0117 | 0.5338 |
| Intermediary 4 | 6 | 0 | 6 | 0.0112 | 0.1333 | 0.4769 |
| Intermediary 5 | 6 | 0 | 6 | 0.0121 | 0.0667 | 0.4706 |
| NU | 2 | 13 | 15 | 0.0316 | 0.0110 | 0.4263 |
| University 1 | 4 | 0 | 4 | 0.0080 | 0.4167 | 0.3975 |
| ND-like 3 | 0 | 16 | 16 | 0.0344 | 0.0 | 0.3795 |
| University 2 | 5 | 0 | 5 | 0.0097 | 0.2000 | 0.3557 |
| ED-like* | 1 | 12 | 13 | 0.0301 | 0.0064 | 0.3015 |
| Big Corporation | 4 | 0 | 4 | 0.0081 | 0.0 | 0.2563 |
| Intermediary 6 | 3 | 0 | 3 | 0.0062 | 0.1666 | 0.2456 |
| CM-like | 0 | 8 | 8 | 0.0181 | 0.0 | 0.2434 |
| EU | 0 | 12 | 12 | 0.0307 | 0.0 | 0.2323 |
| EM | 0 | 10 | 10 | 0.0215 | 0.0 | 0.2248 |
| ED | 0 | 14 | 14 | 0.0354 | 0.0 | 0.2087 |

Table 4 - Whole Network Data Table (up to all case studies)

**This SME exhibits "mixed behaviour" as though it is an "established" firm, its Space-specific offer has only been developed recently within a small cluster of projects led by a new young team, who behave more like an ND-like company.*